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AN APPRAISAL OF CURRENT PRACTICES FOR THE MANAGEMENT OF URANIUM MILL TAILINGS

CHAPTER 6: RESEARCH AND DEVELOPMENT;

PRESENT AND PLANNED RESEARCH, AND PERCEIVED GAPS IN RESEARCH EFFORT

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AUGUST 1977

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ABSTRACT

A summary of current research on the management of wastes from the uranium mining industry which is presently being performed or is in the planning stage, in Canada, is presented. It has been compiled as a contribution to a Green Paper being prepared for the Honorable Alistair Gillespie, Minister of Energy, Mines and Resources Canada, by the Atomic Energy Control Board.

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Chapter 6: Research & Development; Present and Planned Research and Perceived Gaps in Research Effort

INTRODUCTION

When the uranium mining industry was first launched in the mid-fifties, the wastes were considered to be no different than those of any other mining operation and the tailings management facilities that were provided were essentially the same as those common to all mine-mill operations. Since then, science and public concern have clearly demonstrated that 1) all mine-mill wastes, and particularly those of typical Canadian sulphide mineral type ore deposits, are potentially deleterious to the environment and 2) uranium mine-mill wastes represent, in addition, a human health hazard because they contain compounds of radioelements, some of which can dissolve in water and others which emit harmful radiation and release radioactive gases to the air.

There are thus two dimensions to the waste management problem, one that it has in common with most other mining operations, the other specific to the uranium industry. In view of the known and unknown implications of radioactivity to human health, the latter dimension greatly outweighs the former.

OUTLINES OF RESEARCH REQUIREMENTS

Engineering Aspects

Waste management requirements of an engineering nature that are common to all mining operations and hence relevant to the problem of the dispersion of radioelements from uranium wastes

include:

1) The verification of the suitability of the tailings site from an engineering and hydrologic point of view;

2) The transportation of the tailings from the mill and the method used to discharge them into the tailings basin, to minimize accidents and ensure predictable behaviour;

3) The design and construction of tailings retention area and retaining structures to ensure the stability of the piles and to eliminate or control seepage through the dam and the base of the reservoir;

4) On abandonment, stabilization and rehabilitation of the surface to eliminate dusting, erosion and water pollution, and restoration of the appearance and the suitability of the area for appropriate regional land use purposes.

Environmental (non-radioactive) Aspects

The environmental aspects which are not unique to the uranium industry are 1) aesthetics, 2) dust, 3) harmful effects on fish, other wildlife, and vegetation and 4) human health hazards other than radioactivity (toxic elements from the ore and reagents used in processing).

The research requirements need to be subdivided on this basis since considerable work on the non-radioactive components is already underway and proceeding independently of the uranium waste studies. In both cases, the research needs can be further

divided into 1) research needed to establish the nature and extent of the problem, 2) basic studies on the properties of the harmful constituents and the mechanisms leading to their transport into the biosphere, and 3) research on methods to reduce or eliminate this transport.

Environmental and Health Aspects Resulting from the Presence of Radioelements

The waste management requirements that are peculiar to the uranium industry are 1) elimination of the possibility of specific radioelements being transported into the watershed (radium, thorium and lead isotopes) or into the air (radon isotopes) and 2) elimination of the possibility of direct exposure to excessive radiation or radioactive gases resulting from human activities too close to the waste piles or from the transportation of the wastes to populated areas for various uses such as landfill, roadmetal, etc.

Possible approaches to control or elimination of the problems due to the radioactivity of uranium mill tailings are:

1) Short term

Improvements to the current practices which were outlined in previous chapters, for example, improved methods of removing soluble radium from aqueous effluents and seepages, development of methods for their safe disposal, and design of facilities to prevent seasonal upsets leading to uncontrolled discharge of barium radium sludge outside the tailings area.

2) Medium term

a) Improvements in the methods of stabilizing and rehabilitating existing and abandoned tailings areas, and rendering them impervious to leaching and wind erosion, to eliminate seepage of dissolved radioelements and blowing of solid radioactive wastes;

b) The development of alternative, more secure methods for disposal of tailings, for example underground or in deep lakes;

c) The retreatment of existing tailings to remove radioactive elements and pyrite for separate disposal;

d) The removal of the radioelements in concentrated form in the mill using add-on operations to the existing processes, and the development of methods for the safe handling and storage of these wastes.

3) Long term

The development of new processes for uranium recovery with the specific goal of removing all the radioelements in the mill, since it is not definitely known at this point that the present processes can be modified to permit complete separation of the waste radioelements.

Each of the approaches to elimination of known problems will require an evaluation to ensure that they will function as predicted, that they do not introduce new hazards and that they can be supported economically.

CURRENT RESEARCH

A compilation in tabular form of all current research that could be identified in the time available is presented in the Appendix and is summarized in Table 6.1. The same information, classified according to the nature of the research aims, is given in Table 6.2.

TABLE 6.1

Total Research Expenditures, Classified by Organization for 1977-78

Organization	Man-Years	Capital $	Operating $
EMR (CANMET) Minerals Program	14.7	12,500*	25,000*
EMR (CANMET) Energy Program	18.0	6,000	42,800
Fisheries and Environment (Wastewater Technology Centre)	3.3	3,000	25,500
Eldorado Nuclear Ltd.	2.7	300,000	114,500
AECB (sponsored)	∿4.0		100,000
TOTALS	42.7	321,500	307,800

* Includes AECL sponsored work on the nuclear repository.

** AECB expenditure includes $25,000 Operating provided to the Wastewater Technology Centre.

TABLE 6.2

Classification of Information on Research Effort by Type of Project

(does not include engineering and other studies carried out by mining companies and their consultants)

Type of Research Project	MY	Capital $	Operating $
Behaviour of Radium in Soils and Tailings Sludges	sponsored		approx. 20,000
Improvements in Methods of Treating Mine Water and Aqueous Tailings Effluents	1.8	330,000	39,500
Stabilization of Existing Tailings Piles	2.1	5,000	19,000
Revegetation of Tailings Areas	2.90	1,500	90,000
Reprocessing of Tailings *	(2.0)	(500) ↓	(3,000) ↓
Removal of Pyrite and Radium in the Mill, and Development of New Processes *	18.0	6,000	42,800

* The research effort on "Removal of Pyrite and Radium in the Mill" includes the "Reprocessing of Tailings" effort, since the latter work has application to both.

PLANS FOR RESEARCH AND TECHNOLOGY DEVELOPMENT BEYOND THE CURRENT YEAR

Little information was available on this topic. Table 6.3 lists some proposed research by James F. MacLaren Ltd., using consultants. Other work is proposed by the same company on air pollution (dust and radon). Considerable improvement in the quality of mill effluents, particularly with respect to reduction or elimination of thorium, ammonia and nitrates, can be accomplished using known technology. This would only require research to establish applicability and engineering design data and some of this work is also thought to be in the planning stage.

Table 6.4 is a "crystal-ball" estimate of research funding expectations of some organizations over the next 8 years, which would include activities of this type. The availability of funding and man-years is a current constraint on a more rapid expansion of research effort. However, even if this were not the case, the difficulty of finding suitably experienced staff, the building up of research teams and equipping and commissioning laboratories would be rate-determining in any proposed increase in effort.

TABLE 6.3

Partial Forecasts of Total Expenditures on Uranium Processing and Waste Management over the next 8 years (1977-1984) by Some Canadian Organizations

Organization	Total, Salaries and overhead only, $ x 10^6
CANMET	
Waste Management	3.8
Processing	2.3
Eldorado Nuclear Ltd.	
Processing	10.0
Other Major Uranium Producers	20.0

TABLE 6.4

Research Plans of Mining Companies in Conjunction with Jas F. MacLaren Ltd. and Consultants

Consultant	Topic
A.H. Ross and Associates, Ltd.	- Modifications ("add-ons") to current processes, for example pyrite and radium removal.
Goulder Associates	- Long term stabilization of surfaces of tailings areas. - Deep water disposal of tailings, including engineering studies to establish technical and economic feasibility - Characterization of tailings and tailings discharge.

COORDINATION OF RESEARCH

With the rapid growth in research effort that is beginning, the anticipated proliferation of projects and organizations with significant involvement and the relatively limited resources available in each, there is a requirement for formal coordination channels, to ensure that all interests are represented, that research needs can be identified and priorities assigned, and that duplication can be avoided. Table 6.5 lists the coordinating bodies presently operating.

PERCEIVED GAPS IN RESEARCH EFFORT

1. If it is accepted that the ultimate goal of uranium mill waste management is the elimination of pollutants from the tailings, then the effort on tailings retreatment and processes for removal of pollutants in the mill is not being adequately supported.

2. Insufficient effort is going into research on radiochemical analysis, and the staffing and equipping of radiochemical analysis facilities. The problem of obtaining rapid analyses is one of the most serious bottlenecks to current progress.

3. Almost no research is being performed to identify the compounds in which the radium occurs in mill products and tailings. The assumption has been that barium sulphate is the carrier, while recent studies at CANMET indicate that a jarosite (a secondary

TABLE 6.5

Coordinating Committees on Uranium Processing and Waste Management Research

Name	Sponsor	Scope	Terms of Reference	Meets
Uranium Coordinating Committee	EMR Canada	Departmental	Not yet defined	-
Joint Panel on Occupational and Environmental Research for Uranium Production	CANMET, EMR	National, (Government, Industry Labour)	1. To produce an inventory of relevant research being done by supporting members. 2. To exchange information on projected and completed research. 3. To identify research needs and stimulate research activity.	semi annually
Advisory Panel on Tailings	Atomic Energy Control Board	Attendance varies with circumstances	1. To consider long term suitability of uranium mill tailings management. 2. To review the present state of tailings management.	2 month intervals

product produced in milling) and compounds containing lead sulphate may be the most important carriers. Positive identification of the carriers is an important preliminary step to developing methods for radium removal.

4. Little is known at this stage, at least to this writer, about the studies on waste management that have been made by companies other than those in the Elliot Lake, Beaverlodge and Bancroft areas. Some mines in these other areas, because of differences in topography and ore composition, will present a whole range of new environmental concerns.

CONCLUSIONS

A very rough and cursory review and evaluation of current Canadian research effort on the management of waste from Canadian uranium mines and mills has been presented. The information has been mainly derived from planning documents, reports and handouts from those agencies whose work is listed, as well as from the report "Environmental Assessment of the Proposed Elliot Lake Uranium Mines Expansion, Vol. 1 Background Information" by James F. MacLaren Ltd.

APPENDIX A

Details of Research and Development Projects on Uranium Tailings Management

Canada Centre for Minerals and Energy Technology
Ottawa, Ontario and Elliot Lake, Ontario

TABLE A 1

MINING PROGRAM		Description	Schedule	
Project No.	Name		Starting Date	Target Completion Date
3.3.2.4.01	Underground Nuclear Waste Repository	To examine plutonic structures for mechanical and thermal properties to establish their suitability for radioelement storage.	1977	1980
3.3.6.2.01 (EMR-13)	Weathering of Tailings	To select and recommend methods to inhibit natural oxidation of pyrites.	1974	1980
3.3.6.2.02 (EMR-12 -RIO-3) (EMR-15 -RIO-4)	Surface Treatment and Revegetation	a) To rank four types of surface treatments on the basis of contaminant levels and quantity of seepage; and b) to demonstrate the types of vegetation and treatment which will establish self-sustaining growth within five years at a cost of less than $2,500 per acre.	1975	a) 1981 b) 1980
3.3.6.2.03 (EMR-14)	Effluent Control	To establish hydrological, biological and chemical methods for reducing, neutralizing or precipitating acid, heavy metals, radioisotopes and dissolved solids in all discharges from tailings basins or by removal of sources of contamination in the mill. 1) Monitoring water table and seepage from abandoned tailings, also acidity, iron sulphate and radioisotope content; 2) Establishing distribution of Ra^{226}, pyrite and micro-biological activity in an abandoned tailings area; 3) Perform flotation tests and mineralogical examinations to determine the feasibility of pyrite removal from tailings; 4) Explore the possibility of constructing a controlled discharge and settling area for field trials on effluent control.	1975	1980

TABLE A 1

	Schedule		Man Years		Resources 1977-78		Initiated By	Funded By
	Starting Date	Target Completion Date	1977 -78	1978 -79	Capital	Operating		
s for mechanical ablish their suitage.	1977	1980	8.40		-	-	AECL	AECL
ds to inhibit	1974	1980	3.92		8,000 Salaries	8,300 98,000	CANMET	
face treatments on ls and quantity of f vegetation and n self-sustaining ost of less than	1975	a) 1981 b) 1980	1.15		1,500 Salaries	3,300 28,750	CANMET	Assistance from Rio Algom,Ltd.
ological and chemtralizing or pre- radioisotopes scharges from of sources of con-	1975	1980	1.20		3,000 Salaries	13,400 30,000	CANMET	
seepage from abany, iron sulphate								
f Ra^{226}, pyrite ty in an aban-								
mineralogical he feasibility ings;								
constructing a ttling area for ntrol.								

Canada Centre for Minerals and Energy Technology
Energy, Mines and Resources Canada
Ottawa, Ontario

ENERGY PROGRAM		Description	Schedule	
Project No.	Name		Starting Date	Target Comple Date
4.4.5.1.01	Uranium Extraction	To develop environmentally acceptable processes for the recovery of uranium in ores by eliminating or removing pollutants and radioelements in the mill, for sale or safe disposal: a) by finding preconcentration techniques for pyrite control and reagent economy; b) by finding methods to obtain complete dissolution of the radioelements; c) by finding methods to isolate radium safely and in concentrated form;	1976	1981
(EMR-20)	→	d) by establishing the distribution of radium in process streams in existing operating mills; e) by developing rapid accurate methods of chemical analysis to assist research and for application in process control.		

ion	Schedule: Starting Date	Schedule: Target Completion Date	Man Years: 1977-78	Man Years: 1978-79	Resources 1977-78: Capital	Resources 1977-78: Operating	Initiated By	Funded By
ceptable processes n ores by eliminating dioelements in the al: n techniques for economy; in complete dissolu- ate radium safely ution of radium ting operating mills; e methods of chemical n and for application	1976	1981	18	same	6,000 Salaries	42,800 450,000	CANMET	CANMET

Wastewater Technology Centre
Fisheries and Environment Canada
Burlington, Ontario.

Project No.	Name	Description	Schedule	
			Starting Date	Target Complet Date
038	Leachability of Radioactive Constituents from Uranium Mine Tailings		1974	long te
a)	Leachability from Abandoned Tailings and Barium Radium Sulphate Sediments	To establish the effect of time and waterflow on the rate of release of radioactive constituents.		
b)	Leachability from Barium Radium Sulphate Sediment with and without Chemical Fixation	To establish the extent and rate of release of radionuclides from barium radium sulphate residues with and without chemical fixation.		
c)	Leachability from Active Tailings following Chemical/Biological Treatment	To establish the rate of radioactivity leaching from freshly milled tailings and to attempt to reduce this rate by: 1) chemical fixation, 2) addition of air-dried sewage sludge to establish vegetative cover, 3) a combination of 1 and 2. To determine the effect of the above treatments on subsequent coprecipitation of barium radium sulphate.		

	Schedule		Man Years		Resources 1977-78		Initiated	Funded
	Starting Date	Target Completion Date	1977 -78	1978 -79	Capital	Operating	By	By
	1974	long term	2.1		5,000	19,000	Wastewater Technology Centre	Wastewater Technology Centre
and waterflow on ve constituents.								
of release of n sulphate residues on.								
tivity leaching to attempt to								
e sludge to								
ove treatments barium radium								

Wastewater Technology Centre
Fisheries and Environment Canada
Burlington, Ontario

Project No.	Name	Description	Schedule	
			Starting Date	Target Complet Date
069	Physical Chemical removal of Radium	1) Bench scale flocculation tests on mill effluents from Rio Algom and Denison; 2) Settling Curves for tailings decant from Denison; 3) Effect of ultrasonic mixing; 4) Same as 2 using decant from Eldorado Beaverlodge	1976-77	1979

ption	Schedule: Starting Date	Schedule: Target Completion Date	Man Years: 1977-78	Man Years: 1978-79	Resources 1977-78: Capital	Resources 1977-78: Operating	Initiated By	Funded By
tests on mill effluents on;	1976-77	1979	1.2	-	-	6,500	Wastewater Technology Centre	Wastewater Technology Centre
ings decant from								
ing;								
rom Eldorado Beaverlodge								

Wastewater Technology Centre
Canada Centre for Inland Waters
Fisheries and Environment Canada
Burlington, Ontario

Project No.	Name	Description	Schedule: Starting Date	Schedule: Target Completio Date
069 (accelerated)	Reduction of Radium Contents of uranium mill effluents to below 10 pCi/l by improvements in barium radium sulphate precipitation	Phase 1: Bench scale studies on settling and flocculation to provide information for pilot plant design. Upgrading of Analytical facilities.	Sept. 1977	March 1978
		Phase 2: Pilot plant studies of process over two winters using mechanical dewatering.	April 1978	March 1979

tion	Schedule: Starting Date	Schedule: Target Completion Date	Man Years: 1977 -78	Man Years: 1978 -79	Resources 1977-78: Capital	Resources 1977-78: Operating	Initiated By	Funded By
s on settling and ovide information for .	Sept. 1977	March 1978			30,000	25,000	WWTC	in part by AECB
tical facilities.								
s of process over mechanical dewatering.	April 1978	March 1979		3.5	?	150,000	WWTC	in part by AECB

Eldorado Nuclear Limited
R&D Division
Ottawa, Ontario

Project No.	Name	Description	Schedule	
			Starting Date	Target Completi Date
ENL-3	Investigate methods of recovering uranium from mine water and assess the effect of mine water additions to tailings on radium levels in the effluent.	The use of mine water filtrate (after removal of uranium) to replace fresh water for the transport of tailings is proposed. The effect of the salt content of the mine water on radium levels is to be investigated.	1976	1980
ENL-4	To investigate and assess the quality of effluents from present treatment procedures and escape of elements in addition to radium.	1) The monitoring of the present treatment system for radioelements and heavy metals, 2) Determining the effect of present treatment procedures on receiving waters, 3) Development of alternative effluent treatment systems.	ongoing	
ENL-2	Revegetation of Beaverlodge tailings.	Evaluation of revegetation for tailings stabilization (work done in other areas may not be applicable due to the alkaline nature of the tailings and the severe climatic conditions).	1977	1981
ENL-?	Radium balance in Beaverlodge mill.	No details	planning stage	
ENL-?	Assessment of removal of radium and thorium in the mill circuit.	No details	planning stage	

ion	Schedule: Starting Date	Schedule: Target Completion Date	Man Years: 1977-78	Man Years: 1978-79	Resources 1977-78: Capital	Resources 1977-78: Operating	Initiated By	Funded By
e (after removal of er for the transport t of the mine water estigated.	1976	1980	0.6	1.2		18,000	Eldorado	Eldorado
sent treatment system vy metals, present treatment aters, effluent treatment	ongoing		0.3	-	-	10,000	Cooperative, Federal Provincial	Eldorado
r tailings stabiliza- s may not be appli- ture of the tailings tions).	1977	1981	1.75	-	-	86,500	Eldorado	Eldorado
	planning stage							
	planning stage							

Project No.	Name	Description	Schedule Starting Date	Schedule Target Completion Date
Physics Department University of Calgary Calgary, Alta. Dr. C.J. Bland				
Contract OSU76-00147	Study on the Chemical and Physical Stability of Barium/Radium Sulphate Sludges	Investigation of the effect of temperature pH, and dissolved sulphate concentration of the aqueous solution in which the sludge is submerged, using synthetic sludges and radioactive tracers for barium and sulphur.	1976	1977
Chemical Engineering and Applied Chemistry Dept. University of Toronto Toronto, Ontario Dr. Colin Phillips				details not
	Study on the leaching of soil contaminated by radium-bearing mill wastes, and the migration of the radium.	Investigation of the leaching of radium from soil by simulated acidic and carbonatic rain water, and its subsequent migration through the soil. Planned: work aimed at developing strategies for the removal of radium during uranium extraction in the mill.		

tion	Schedule Starting Date	Schedule Target Completion Date	Man Years 1977-78	Man Years 1978-79	Resources 1977-78 Capital	Resources 1977-78 Operating	Initiated By	Funded By
ect of temperature pH, oncentration of the h the sludge is sub- sludges and radio- um and sulphur.	1976	1977			-	$10,160.00	CANMET	CANMET
leaching of radium from idic and carbonatic rain quent migration through at developing strategies emoval of radium during xtraction in the mill.	details not available				details not available		details not available	

In addition, the following is a list of projects, on wh-

TABLE A 2

Denison Mines Ltd.
Elliot Lake, Ontario

Organization	Project Number	Project Title
Denison Mines Ltd.	DEN-5	Effect of filter pore size on the Dissolved Radium Acceptability Criteria in Ontario Water Quality Objectives.
Denison Mines Ltd.	DEN-6	A Feasibility Study for Pyrite Removal from Mill Tailings.
Denison Mines Ltd.	DEN-7	Pyrite (and radioelement) Distribution in Mine Backfill Products.
Denison Mines Ltd.	DEN-8	Sulphuric Acid Elution
Denison Mines Ltd.	DEN-9	Serpent River Radium Deposition

is a list of projects, on wh

TABLE A 2

t Title	Description
ct of filter pore size on the solved Radium Acceptability Criteria Ontario Water Quality Objectives.	Investigate and quantify the variations that might occur using 3.0 micron instead of 1.2 micron Millipore filters.
Feasibility Study for Pyrite Removal om Mill Tailings.	Study the effects and economics of pyrite removal to produce pyrite-free tailings.
yrite (and radioelement) Distribution in Mine Backfill Products.	To determine to distribution of the pyrite, uranium, radium and thorium in the sand and slime fractions of the proposed sand backfill plants.
Sulphuric Acid Elution	To determine the effects of sulphuric acid elution in the ion exchange process with a view to reducing nitrogen compounds in mill effluent.
Serpent River Radium Deposition	To determine the extent, if any and location of barium/radium sulphate deposits along the Serpent River.

TABLE A 3

Atomic Energy Control Board
Sponsored Research

Organization	Project Number	Project Title	Description
Atomic Energy Control Board (Sponsor)	#2	An Investigation of Methods for the Removal of Radium from Uranium Mill Tailings Effluents	To develop mechanical techn tion of suspended radium i effluent for ready industr
Atomic Energy Control Board (Sponsor)	#3	The Assessment of the Long-Term Suitability of Present and Proposed Methods for the Management of Uranium Tailings	To examine present and prop tailings management using that the most desirable me continued surveillance - 6 months project -
Atomic Energy Control Board (Sponsor)	#4	Geochemical Studies of the Movement of Radium in Soils.	To obtain information on th by typical Canadian soils s predict consequences of ent by groundwater-laboratory e work.

TABLE A 3

	Description	M-Y	Cost	Contractor
thods for the Uranium Mill	To develop mechanical techniques for the reduction of suspended radium in final tailings effluent for ready industrial implementation	see Wastewater Technology Centre Project 069		WWTC
ong-Term and Proposed ent of Uran-	To examine present and proposed methods of tailings management using the target criterion that the most desirable method will not rely on continued surveillance - 6 months project -	2	$75,000	not selected
the Move-	To obtain information on the uptake of radium by typical Canadian soils so as to be able to predict consequences of entrainment of radium by groundwater-laboratory experiment and field work.	1-2	not established	University of Waterlo